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by
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Washington 25, D. C.

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FOREWORD

This report describes the progress made in August 1963 on work performed in the Research Division of National Research Corporation under Contract No. NASw-734 for the National Aeronautics and Space Administration.

The general object of the work is to obtain additional information as to the conditions under which metals and alloys of engineering importance for space applications will adhere to one another with sufficient tenacity to hinder the relative motion or subsequent separation of components of mechanical and electrical devices, used in space exploration. Such devices include bearings, solenoids, valves, slip rings, mating flanges, conical rendezvous mating surfaces and similar components.

ABSTRACT

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During August four more pairs of soft copper specimens and four more pairs of soft 1018 steel specimen were tested in vacuum. Three steel pairs and two of the copper pairs were thoroughly wire brushed below 2.5×10^{-9} torr and pushed together within 30 seconds after brushing. Compressive stresses sufficient to cause approximately .005 inches deformation on each sample were employed. One copper pair remained apart 70 seconds after brushing and one was not brushed. One steel pair was held in compression for 11 minutes. As in the previous tests (see Table 1 of July report) cohesion occurred between the wire brushed copper samples only. However, the cohesive forces were about three times greater than in the previous tests; the largest force measured being 120 lbs*. This was ascribed to two more thorough wire brushings.

The remainder of the month was spent in experimenting with the ion guns. Minor changes in design and the procurement of a new high voltage power supply appear to be necessary.

* Surface area .064 sq.in.

COHESION EXPERIMENTS WITH WIRE-BRUSH CLEANING

Eight soft copper specimens and eight soft 1018 steel specimens were polished on 000 aloxite abrasive paper as usual. With four soft copper specimen pairs and four 1018 specimen pairs in place the apparatus was pumped down and baked out at 282°C. The maximum pressure (4.4×10^{-6} torr) occurred at 225°C. Final pressure at 282°C was 1.5×10^{-6} torr. Final pressure at room temperature was 1.0×10^{-9} torr. Each pair of specimens (except one) was then wire brushed and pushed together until it deformed about .010 inches (.005 inches on each side). One of the copper pairs was pushed together without wire brushing and one pair was allowed to stand for 10 minutes at 1.4×10^{-9} torr after wire brushing before being pushed together. One steel pair was held in compression for 11 minutes. The results and exact conditions of the tests are recorded in Table I.

All of the soft copper specimens except the one not wire brushed stuck together with measurable force, but none of the steel specimens stuck together with measurable force. The largest cohesive force obtained was 120 lbs.* which represents a cohesion coefficient of 120/2000 or 0.06. In this test the specimens were intentionally left apart for 10 minutes at 1.4×10^{-9} torr. However, this represents an exposure of only 1.4×10^{-8} torr/min. which is sufficient for only a small fraction of a monolayer to form. Therefore, it was assumed that the cleanliness of all three of the stuck copper pair was the same. It is also believed that the thoroughness of the brushing was about the same in each case. From test number 3 and from a previous similar test, the brushing is

* Surface area .064 sq. in.

TABLE I
Adhesion Run No. 2

Test	Material		Comp. Force (lbs.)	Contact Area ₂ (in. ²)	Deformation (mils)		Comp. Stress (psi)	Cohesive Force lbs.	Time Together (sec)	Time Apart After Brushing (sec)	Pressure While Apart (torr)
	Top	Bottom			Top	Bottom					
1	Soft Cu	Soft Cu	2000	.0702	3.6	4.5	51,700	60	60	70	2×10^{-9}
2	Soft Cu	Soft Cu	1950	.0668	4.7	4.5	55,550	100	60	30	2.4×10^{-9}
3	Soft Cu	Soft Cu	2000	.0668	6.1	5.7	57,000	0*	60	*	1.4×10^{-9}
4	Soft Cu	Soft Cu	2000	.0635	5.3	6.4	63,200	120	60	600	1.4×10^{-9}
5	Soft 1018 Steel	Soft 1018 Steel	2800	.0202	4.6	5.0	88,700	#	#	30	1.5×10^{-9}
6	Soft 1018 Steel	Soft 1018 Steel	2300	.0216	2.3	2.3	62,800	0	60	30	1.8×10^{-9}
7	Soft 1018 Steel	Soft 1018 Steel	2400	.0172	4.9	4.2	103,300	0	660	30	1.0×10^{-9}
8	Soft 1018 Steel	Soft 1018 Steel	-	-	-	-	-	-	-	-	No Test

* - No Brushing

- Pin Sheared

known to be effective either because of the roughing effect or the cleaning effect or both, and it is believed that the thoroughness of the brushing was about the same for all the specimens in this run. Therefore, it is concluded that the observed differences in cohesive force (60,100 and 120 lbs.*) reflect differences in the applied stress (51,700, 55,550 and 63,200 psi) and deformation (8.6, 9.2 and 11.7 mils). The specimen not wire brushed gave zero cohesion even though the stress was 11,800 psi and the deformation was 11.8 mils. The fact that the steel did not bond even in 11 minutes after 9.1 mils total deformation indicates that either hardness or degree of roughening or both is indeed an important factor. The brushing causes less roughening of the steel than of the copper.

ION GUN EXPERIMENTS

The ion guns described in earlier reports were then assembled, mounted and pumped down and various D-C voltages applied to the elements while varying the pressure of xenon. Plates coated with a phosphor and grounded through a microammeter were used as targets instead of specimens.

The major problem with the ion guns has been the maintenance of a sufficient ion current between the orifice plate and the gas inlet cone to furnish the required reservoir of positive ions. The xenon inlet pressure was varied from 25 microns to 300 microns, corresponding to 5×10^{-6} torr and 9×10^{-5} torr vacuum chamber

* Surface area .064 sq.in.

pressure. (The gas pressure attenuation factor at orifice is about 3000.) The orifice plate was kept at +200 volts above ground, since it determines the final ion velocity and higher voltages are reported to cause xenon occlusion. At first, discharge occurred through the external glass tubing to the metering valves. After these were insulated 400 μ a was obtained in the reservoir at 160 to 190 microns Hg xenon pressure using 500 volts D-C. With 2 kv on the ion extractors, only $.4 \times 10^{-10}$ amps ion current was thus obtained. At 3 kv a small negative current was obtained at the target and at 5 kv an erratic discharge occurred. Application of a Tesla coil to either the orifice plate of the inlet cone doubled the ion current in the reservoir but interfered with the microammeter reading to the target.

The following measures are being taken in an effort to establish an ion beam. The magnets were removed from one gun (two are being tested) in order to simplify internal insulation problems and reduce the apparent resistance of the gas in front of the orifice plate. The other gun was fitted with a tungsten filament heater inside the inlet cone near the orifice. An RF oscillator (150 watt at 27 mc) was obtained to assist in generating ions and a higher voltage supply ordered for the ion extractor. The results of these changes have not yet been evaluated.

PLANS

It is assumed that the ion guns will be operable in a short time and that the four soft copper and four soft steel pairs can be run as planned to compare ion bombardment with wire brushing. However, in the event that the guns cannot be made to operate in the short time remaining all of the tests involving soft copper will be made by the wire brushing technique. This will require one run with eight soft copper specimens in one wheel and one of each of the other six metals in their soft condition in the other wheel. One hard copper specimen and one soft copper specimen will be placed in the other two stations. The soft copper to soft copper test in this run will be wire brushed in air before pumping down and will not be wire brushed in vacuum. This will determine whether the effect of wire brushing is due to roughening or to channing. Since it appears unlikely that flat faces of any of the other pairs of harder metals will adhere after wire brushing sixteen of the remaining samples will be remachined to form 90° crossed chisel edges. This will increase the deformation tremendously for a given load and will also cause sliding when one metal is harder than the others. These tests can then be repeated using wire brushing and in a later program ion bombardment. However, if the ion guns work in a short time and cause significantly more adhesion between flat faces than wire brushing the present specimen shape will be retained and all of the samples will be tested after ion bombardment. The actual testing requires a very short time compared to the preparatory work.